**Do not open the exam until you are told to do so.**

**Cell phones and other electronic devices must be turned off and stowed out of sight (your sight and mine). Calculator policy is in effect. Infractions will cost you points!**

**ALL outside paper must be stowed out of sight. Unauthorized materials will result in your exam being removed and a score of 0 assigned.** If you reach a point where you need more scratch paper than the space available, ask a proctor.

**Please clearly and legibly write your name, in ink, at the top of both pages of your answer sheet. Your score will not be recorded and your exam will not be returned if this is not done.**

All answers should be rounded to the appropriate precision (correct significant figures.)

Atomic weights are provided in the Periodic Table. These values must be used.

Be certain your answers are clear. If an answer is not clear, it will probably be considered wrong.

Use your time effectively.

When authorized to open your exam, you may carefully remove this cover sheet. When you are finished with your exam, please turn in **the two answer sheets.**

Make sure your name is clearly written **on every page**.

**Time is up at 12:15!!**

# THE PERIODIC TABLE

| | 1 (1A) | 2 (2A) | 3 (3B) | 4 (4B) | 5 (5B) | 6 (6B) | 7 (7B) | 8 | 9 (8B) | 10 | 11 (1B) | 12 (2B) | 13 (3A) | 14 (4A) | 15 (5A) | 16 (6A) | 17 (7A) | 18 (8A) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 H 1.008 | | | | | | | | | | | | | | | | | 2 He 4.003 |
| 2 | 3 Li 6.941 | 4 Be 9.012 | | | | | | | | | | | 5 B 10.81 | 6 C 12.01 | 7 N 14.01 | 8 O 16.00 | 9 F 19.00 | 10 Ne 20.18 |
| 3 | 11 Na 22.99 | 12 Mg 24.31 | | | | | | | | | | | 13 Al 26.98 | 14 Si 28.09 | 15 P 30.97 | 16 S 32.07 | 17 Cl 35.45 | 18 Ar 39.95 |
| 4 | 19 K 39.10 | 20 Ca 40.08 | 21 Sc 44.96 | 22 Ti 47.87 | 23 V 50.94 | 24 Cr 52.00 | 25 Mn 54.94 | 26 Fe 55.85 | 27 Co 58.93 | 28 Ni 58.69 | 29 Cu 63.55 | 30 Zn 65.38 | 31 Ga 69.72 | 32 Ge 72.64 | 33 As 74.92 | 34 Se 78.96 | 35 Br 79.90 | 36 Kr 83.80 |
| 5 | 37 Rb 85.47 | 38 Sr 87.62 | 39 Y 88.91 | 40 Zr 91.22 | 41 Nb 92.91 | 42 Mo 95.96 | 43 Tc (98) | 44 Ru 101.1 | 45 Rh 102.9 | 46 Pd 106.4 | 47 Ag 107.9 | 48 Cd 112.4 | 49 In 114.8 | 50 Sn 118.7 | 51 Sb 121.8 | 52 Te 127.6 | 53 I 126.9 | 54 Xe 131.3 |
| 6 | 55 Cs 132.9 | 56 Ba 137.3 | 57 La 138.9 | 72 Hf 178.5 | 73 Ta 180.9 | 74 W 183.8 | 75 Re 186.2 | 76 Os 190.2 | 77 Ir 192.2 | 78 Pt 195.1 | 79 Au 197.0 | 80 Hg 200.6 | 81 Tl 204.4 | 82 Pb 207.2 | 83 Bi 209.0 | 84 Po (209) | 85 At (210) | 86 Rn (222) |
| 7 | 87 Fr (223) | 88 Ra (226) | 89 Ac (227) | 104 Rf (265) | 105 Db (268) | 106 Sg (271) | 107 Bh (272) | 108 Hs (277) | 109 Mt (276) | 110 Ds (281) | 111 Rg (280) | 112 Cn (285) | 113 Uut (284) | 114 Uuq (289) | 115 Uup (288) | 116 Uuh (293) | 117 Uus (294) | 118 Uuo (294) |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 58 Ce 140.1 | 59 Pr 140.9 | 60 Nd 144.2 | 61 Pm (145) | 62 Sm 150.4 | 63 Eu 152.0 | 64 Gd 157.3 | 65 Tb 158.9 | 66 Dy 162.5 | 67 Ho 164.9 | 68 Er 167.3 | 69 Tm 168.9 | 70 Yb 173.0 | 71 Lu 175.0 |
| 90 Th 232.0 | 91 Pa 231.0 | 92 U 238.0 | 93 Np (237) | 94 Pu (244) | 95 Am (243) | 96 Cm (247) | 97 Bk (247) | 98 Cf (251) | 99 Es (252) | 100 Fm (257) | 101 Md (258) | 102 No (259) | 103 Lr (262) |

Based on IUPAC 2007 (publ 2009).

## Potentially useful information:

**Avogadro's number:** $6.022 \times 10^{23}$

**Temperature conversion:** $T(K) = T(°C) + 273$

**Gases:** one atm = 760 mmHg = 760 torr $PV = nRT$ $R = 0.08206$ (L atm)/(mol K)

$$d = \frac{M \times P}{RT} \qquad u_{rms} = \sqrt{\frac{3RT}{M}} \qquad \frac{rate_A}{rate_B} = \sqrt{\frac{M_B}{M_A}}$$

**Heat and heat capacity:** $q = C \times mass \times \Delta T$

**Electromagnetic Radiation:** $E = h\nu = hc/\lambda$ $h = 6.626 \times 10^{-34}$ J·s $c = 3.00 \times 10^{8}$ m/s

**Electron energy:** $E = -2.18 \times 10^{-18} J\left(\frac{Z^2}{n^2}\right)$

name________________________________

Please circle your Recitation time:

9:00 10:00 12:00 4:00

| Do not write in this space. |
| --- |
| Page totals: 1_______ |
| 2_______ |
| 3_______ |
| 4_______ |
| Total score: __________ |

1. The following thermochemical equations are provided. Circle the correct answer for each question. *Note: all of the problems on this page are independent of each other; your answer to one problem does not depend on having a previous problem correct. Use your periodic table for scratch paper; raise your hand if you need more scratch paper.*

Eq. 1 $\mathbf{2\ O_3\ (g) \rightarrow 3\ O_2\ (g)}$ $\Delta H^o_{rxn} = -\ 427$ kJ/mol

Eq. 2 $\mathbf{O_2\ (g) \rightarrow 2\ O\ (g)}$ $\Delta H^o_{rxn} = +\ 495$ kJ/mol

Eq.3 $\mathbf{NO\ (g) + O_3\ (g) \rightarrow NO_2\ (g) + O_2\ (g)}$ $\Delta H^o_{rxn} = -\ 199$ kJ/mol

a. [2 pts] How much energy, in kJ, is required to break the O=O bond in one mole of $O_2$?

+661 +495 +466 +427 +248 +233 +214 +199 +131

–661 –495 –466 –427 –248 –233 –214 –199 –131

b. [4 pts] Calculate the $\Delta H^o_{rxn}$, in kJ/mol, for $\mathbf{NO\ (g) + O\ (g) \rightarrow NO_2\ (g)}$

+661 +495 +466 +427 +248 +233 +214 +199 +131

–661 –495 –466 –427 –248 –233 –214 –199 –131

c. [3 pts] Stoichiometric amounts of NO and O are combined in a 5.2-liter container at room temperature and allowed to react: $\mathbf{NO\ (g) + O\ (g) \rightarrow NO_2\ (g)}$. Before the reaction, the total pressure in the container is 0.048 atm. What is the pressure, **in atm**, after the reaction is complete and the product mixture has returned to room temperature?

0.016 0.024 0.026 0.048 0.052 0.0821 0.096 0.25 1.0 1.6

2.4 2.6 4.8 5.2 9.6 10.4 11.2 14.4 22.4

d. [4 pts] What volume, in L, would be occupied by 5.52 g of NO at 24ºC and 752 mm Hg (the approximate temperature and pressure in this room)?

0.000482 0.00596 0.00735 0.0145 0.221 0.366 0.454

4.06 4.44 4.53 5.52 0.989 22.4 124 136

name________________________________________

2. [18 pts, 2 each] Supply an appropriate example of each of the following. In some cases there could be more than one acceptable answer; pick **one**.

__________________ An element with valence electrons in the 5p sublevel.

__________________ A substance that has a $\Delta H^0_f$ of 0. (Include appropriate phase label.)

__________________ An allowed value of $\ell$ for an electron in the n=2 level.

__________________ An element that exists under standard conditions as **individual gas-phase atoms**.

__________________ A neutral atom with 3 valence electrons.

__________________ A neutral atom with 3 unpaired electrons.

__________________ The total number of electrons in a filled 7g **orbital**.

__________________ The Period 6 element with the largest atomic radius.

__________________ A neutral atom that is diamagnetic.

3. [16 pts, 2 each] **Clearly** indicate whether each statement is TRUE or FALSE. If we can't tell which you mean, it's wrong.

_________________ An electron relaxing from n=2 to n=1 absorbs a photon.

_________________ The longer the wavelength of a photon, the greater its energy.

_________________ One mole of an ideal gas occupies 22.4 L of volume, regardless of conditions.

_________________ The ideal gas law works best when gas molecules are relatively close together.

_________________ The majority of elements in the periodic table are diamagnetic as neutral atoms.

_________________ The 4d sublevel has a capacity of 10 electrons.

_________________ Main-group elements often form ions with noble-gas electron configurations.

_________________ In an exothermic reaction, energy flows from a system into the surroundings.

name______________________________

4. a. [3 pts] Give a ground-state valence orbital diagram (or "box diagram") for an atom of silicon. (Write your answer in the box.)

a.

b. [3 pts] Give the ground-state, condensed electron configuration for an iron(II) ion. (Write your answer in the box.)

b.

5. [12 pts, 2 each] Consider two 1-L samples of gas: one is $O_2$ and the other is $H_2$. Both are at 1 atm and 25 ºC. Circle your choice for each of the following quantities or values.

| | | | |
|---|---|---|---|
| a. greater average kinetic energy of molecules: | $O_2$ | $H_2$ | both the same |
| b. greater number of gas particles: | $O_2$ | $H_2$ | both the same |
| c. faster average molecular speed: | $O_2$ | $H_2$ | both the same |
| d. greater mass: | $O_2$ | $H_2$ | both the same |
| e. greater time required for a given fraction of molecules to effuse: | $O_2$ | $H_2$ | both the same |
| f. higher density: | $O_2$ | $H_2$ | both the same |

6. [18 pts, 2 each] For each of the following, select the **greatest** value and circle your choice.

| | | | | |
|---|---|---|---|---|
| a. radius: | Fe | $Fe^{2+}$ | $Fe^{3+}$ | all the same |
| b. number of orbitals: | in 5s sublevel | in 3d sublevel | in 4p sublevel | all the same |
| c. energy of photon of light: | orange | blue | UV | all the same |
| d. number of valence electrons: | O | Se | both the same | |
| e. atomic size: | C | O | Be | all the same |
| f. ionic radius: | $N^{3-}$ | $O^{2-}$ | $F^{-}$ | all the same |
| g. number of unpaired electrons: | $N^{3-}$ | $O^{2-}$ | $F^{-}$ | all the same |
| h. first ionization energy: | Cl | Ar | Na | all the same |
| i. second ionization energy: | Na | Mg | Al | all the same |

name________________________________________

7. (a) [4 pts] An x-ray has a wavelength of 1.3 Å. Calculate the energy (in J) of one photon of this radiation. (1 Å = $10^{-10}$ m)

| | | | |
|---|---|---|---|
| $8.6 \times 10^{-44}$ J | $1.5 \times 10^{-35}$ J | $1.5 \times 10^{-31}$ J | $1.5 \times 10^{-25}$ J |
| $1.3 \times 10^{-25}$ J | $8.6 \times 10^{-24}$ J | $2.3 \times 10^{-18}$ J | $8.6 \times 10^{-15}$ J |
| $1.5 \times 10^{-15}$ J | $1.3 \times 10^{-10}$ J | $2.3 \times 10^{-8}$ J | $2.3 \times 10^{8}$ J |
| $1.3 \times 10^{10}$ J | $2.3 \times 10^{18}$ J | $1.5 \times 10^{53}$ J | |

8. The $\Delta H^o_f$ values for various nitrogen species are given below. Answer each question appropriately.

$\Delta H^o_f$ values: $NH_4^+$ (aq), –132.5 kJ $NO_3^-$ (aq), –205.0 kJ $NH_4NO_3$ (s), –364.5 kJ $N_2O$ (g), +82.1 kJ

a. [4 pts] Write the **reaction equation** corresponding to the $\Delta H^o_f$ of solid ammonium nitrate. (Appropriate **phase labels** are required for credit.)

b. [4 pts] Calculate the $\Delta H_{rxn}$ for dissolving 1 mol of ammonium nitrate in water, and circle the correct value.

$$NH_4NO_3\ (s) \rightarrow NH_4^+\ (aq) + NO_3^-\ (aq) \qquad \Delta H_{rxn} = ?$$

| | | | | |
|---|---|---|---|---|
| –702.0 kJ | –364.5 kJ | –337.5 kJ | –205.0 kJ | –132.5 kJ |
| –27.0 kJ | 0 kJ | +27.0 kJ | +132.5 kJ | +205.0 kJ |
| +337.5 kJ | +364.5 kJ | +702.0 kJ | | |

c. [2 pts] Based on your answer to (b), when ammonium nitrate dissolves in water, will the solution become warmer or cooler to the touch? ____________________________

d. Ammonium nitrate can be used as an explosive; it was used in the bombing of the Oklahoma City Federal Building and in the first World Trade Center bombing, in 1993. The relevant reaction is:

$$NH_4NO_3\ (s) \rightarrow N_2O\ (g) + 2\ H_2O\ (g) \qquad \Delta H_{rxn} = -37.0\ \text{kJ}$$

[4 pts] How much heat is released when 25.0 g of ammonium nitrate decomposes according to the reaction shown? Circle the correct answer.

| | | | | | |
|---|---|---|---|---|---|
| 0 kJ | 11.6 kJ | 25.0 kJ | 37.0 kJ | 82.1 kJ | 114 kJ |
| 241.8 kJ | 365 kJ | 740. kJ | 925 kJ | 74000 kJ | |